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Park et al.

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(54) **LOOP ANTENNA HAVING MATCHING CIRCUIT INTEGRALLY FORMED**

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Aug. 8, 2006 (KR) 10-2006-0074501

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H01Q 11/12 (2006.01)

(52) **U.S. Cl.** **343/741**; 343/742; 343/866

(58) **Field of Classification Search** 343/741, 343/742, 866
See application file for complete search history.

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(57) **ABSTRACT**

A loop antenna is provided having a matching circuit integrally formed includes a radiator which is formed in a loop shape; and a matching circuit including an extension part extended from one side of the radiator to an inner side of the loop and a bend part bent from an end of the extension part several times. Accordingly, the space for the installation of the loop antenna can be reduced and the design modification of the matching circuit can be facilitated.

15 Claims, 7 Drawing Sheets

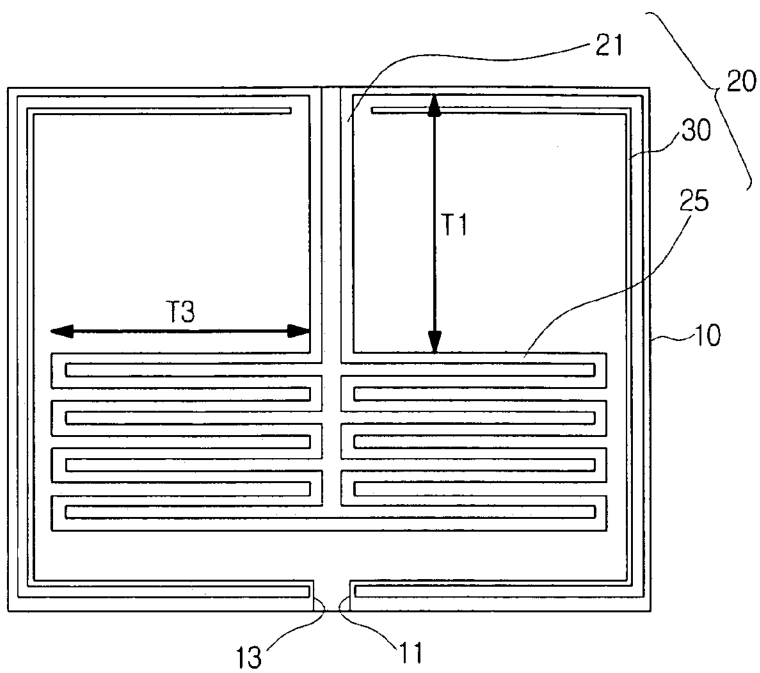


FIG. 1

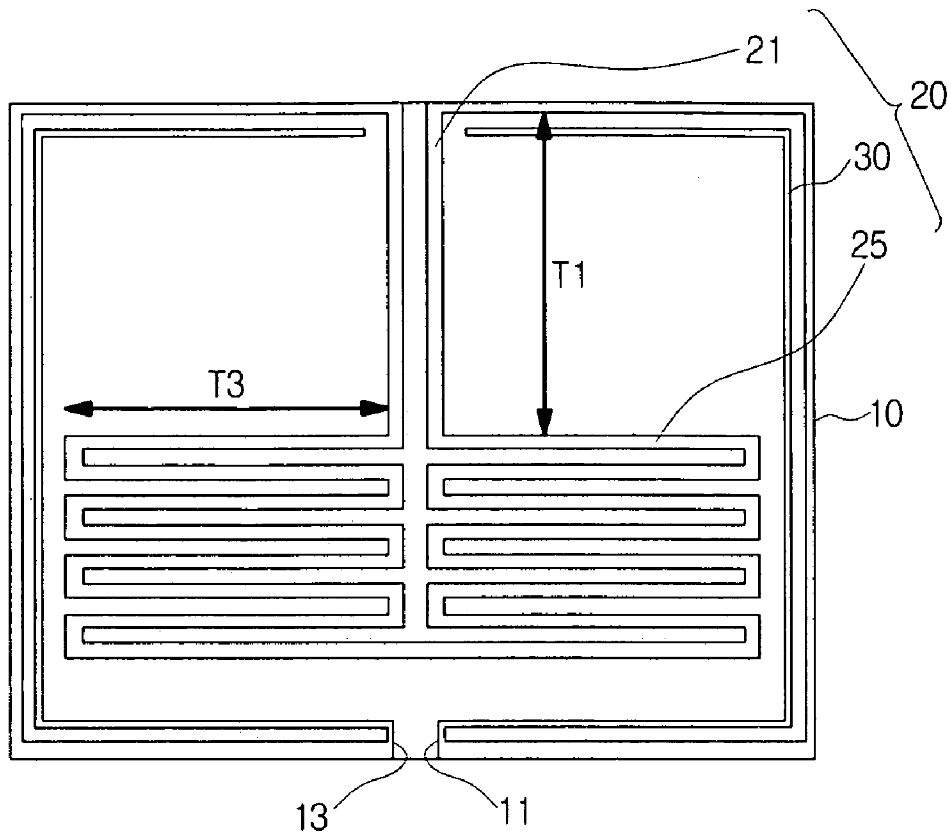


FIG. 2

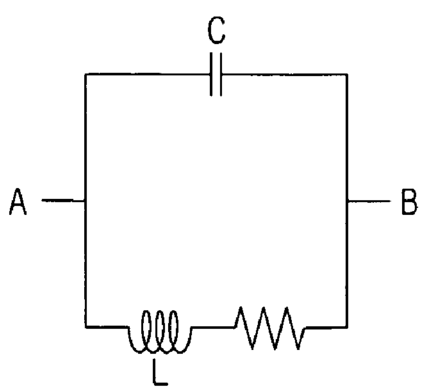


FIG. 3

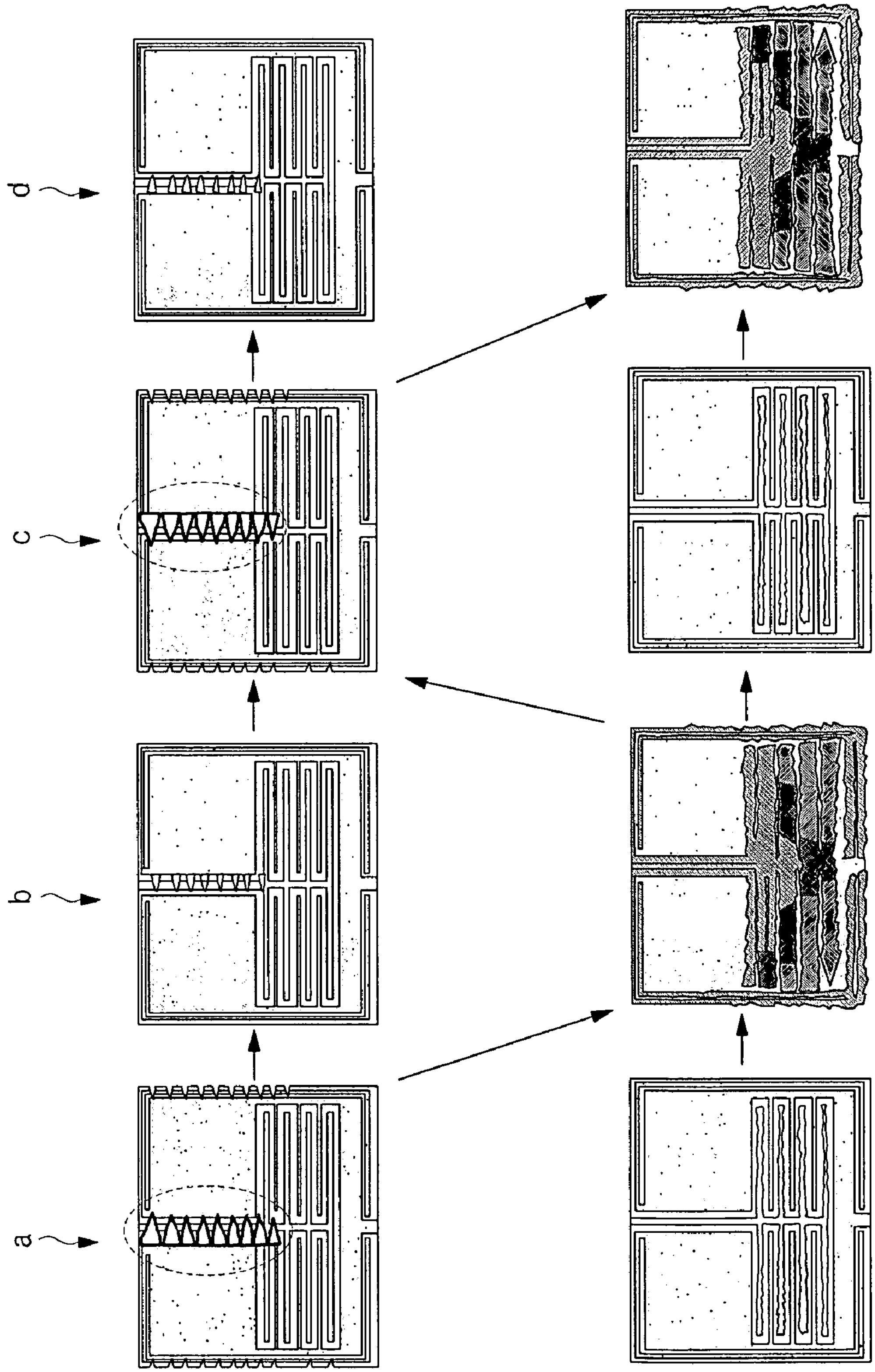


FIG. 4

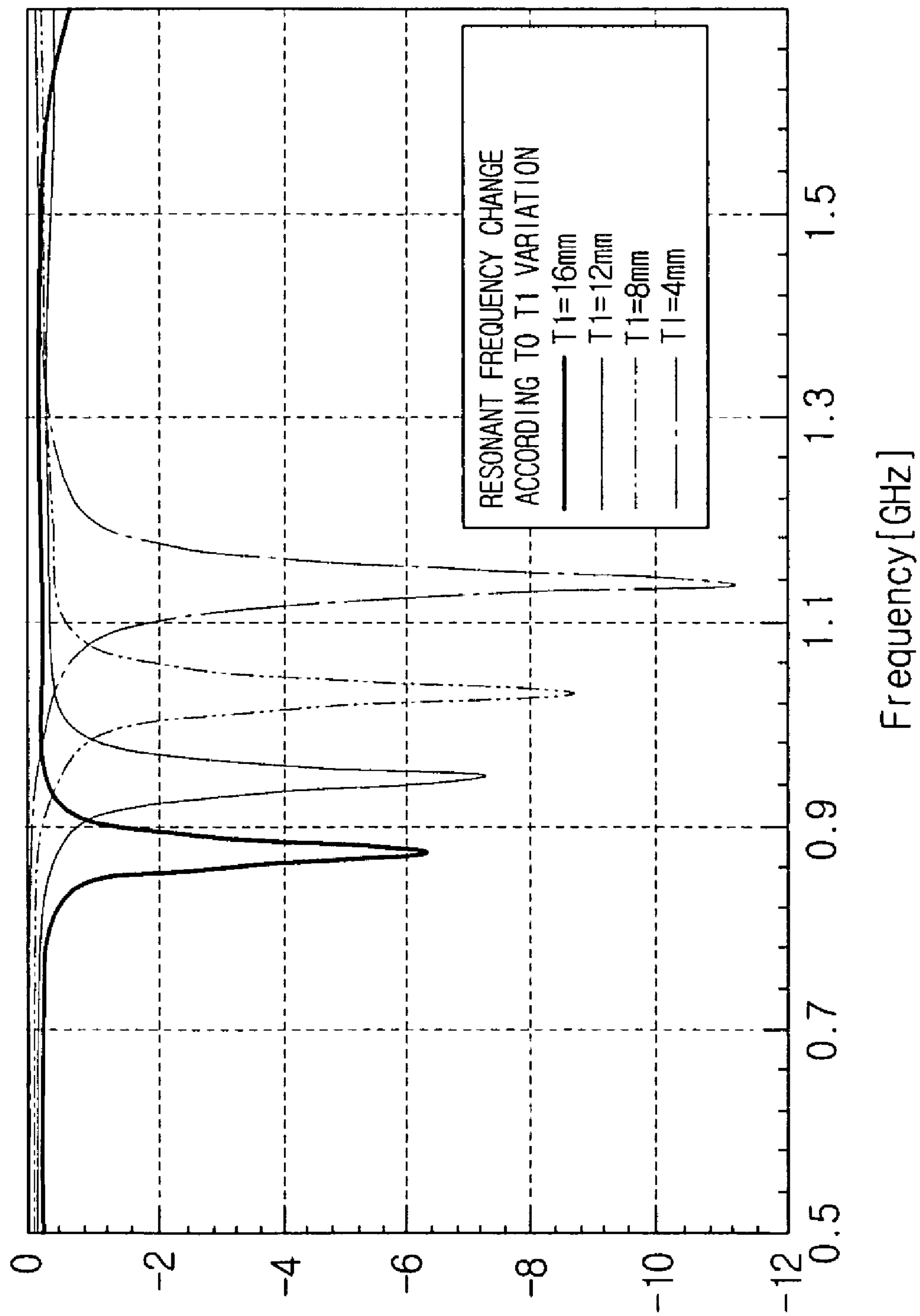
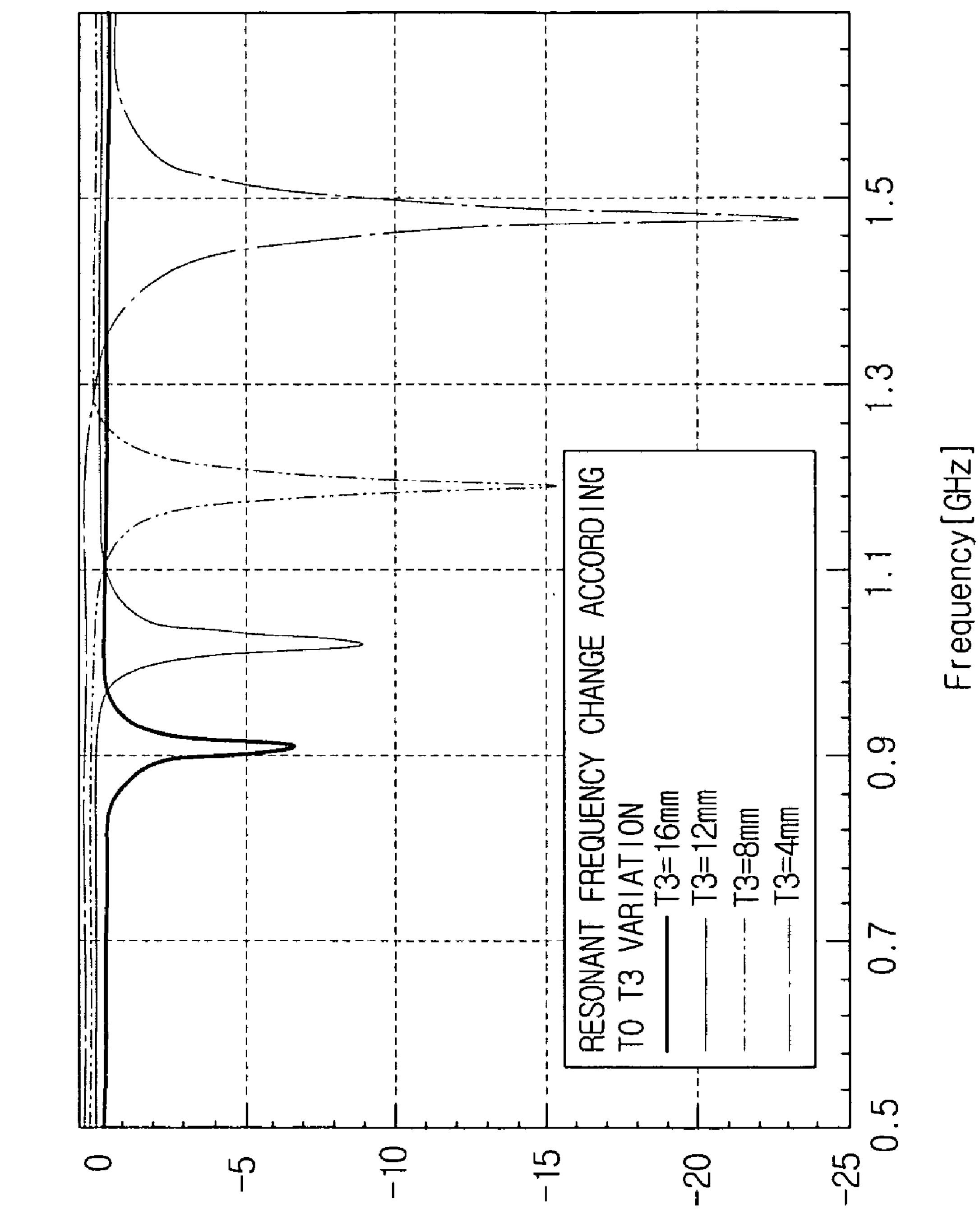

RESONANT FREQUENCY CHANGE
ACCORDING TO T1 VARIATION
T1=16mm
T1=12mm
T1=8mm
T1=4mm
Frequency[GHz]
0.5
0.7
0.9
1.1
1.3
1.5
0
-2
-4
-6
-8
-10
-12

FIG. 5


RESONANT FREQUENCY CHANGE ACCORDING TO T3 VARIATION
T3=16mm
T3=12mm
T3=8mm
T3=4mm
Frequency[GHz]
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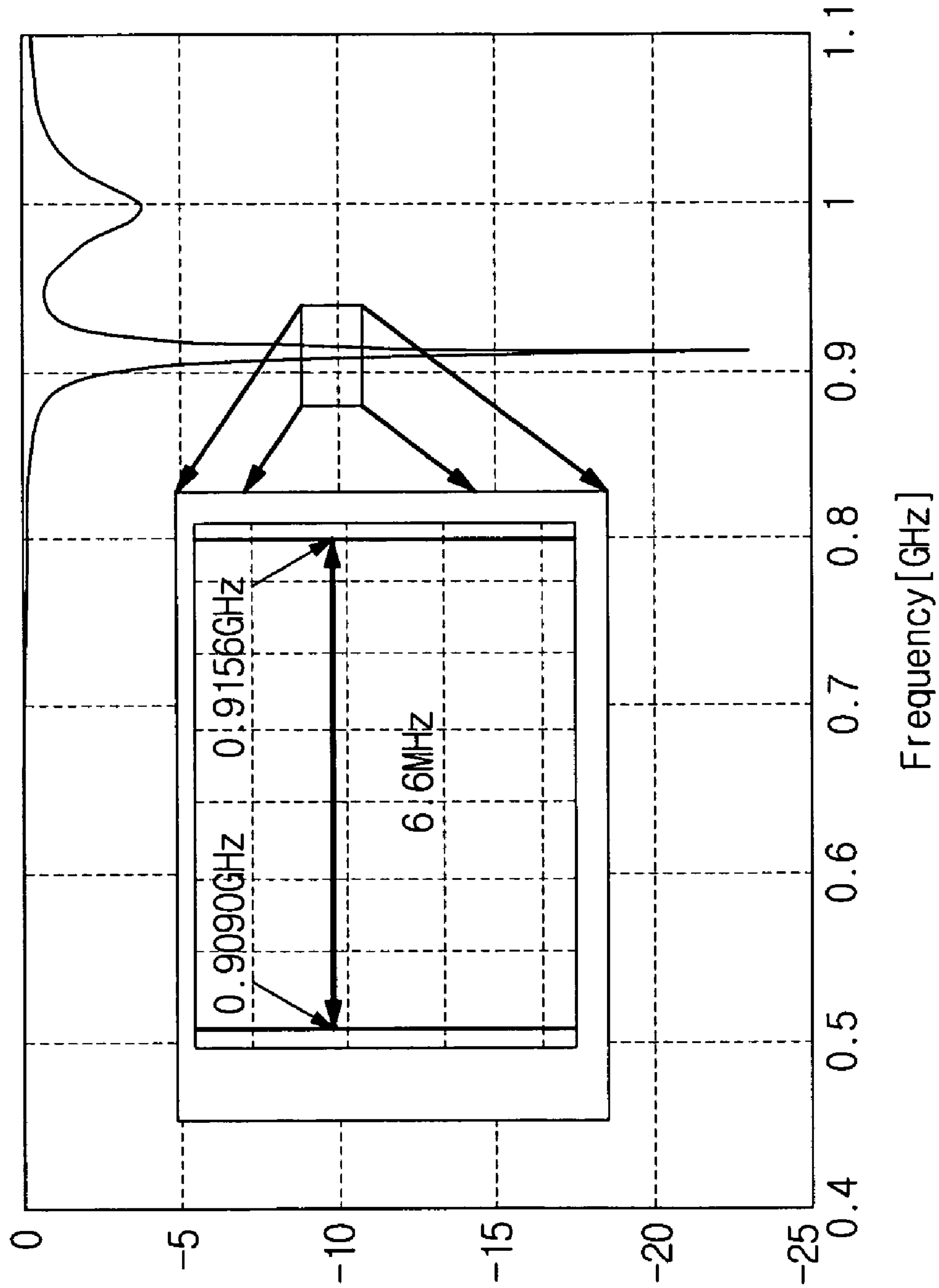
0.7
0.9
1.1
1.3
1.5
0
-5
-10
-15
-20
-25

FIG. 6


0
-5
-10
-15
-20
-25
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
Frequency[GHz]
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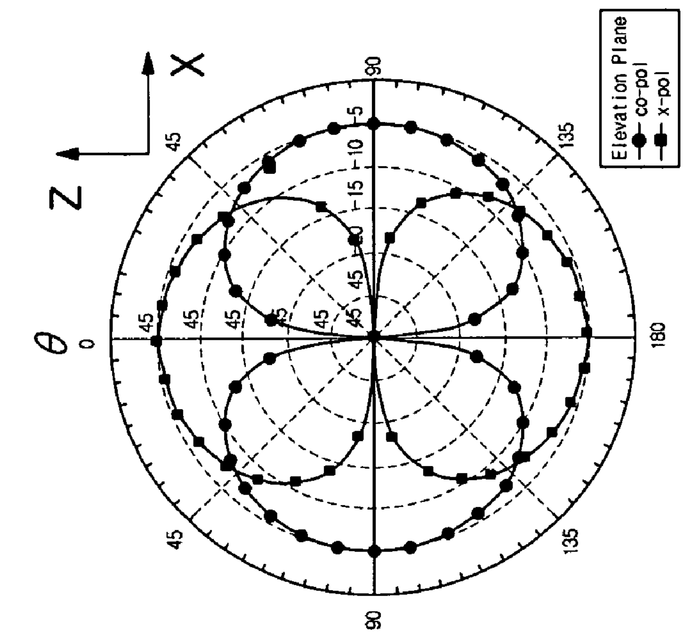
0.9156GHz
6.6MHz

FIG. 7B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co-pol
x-pol
Z
X
θ
0
45
90
135
180

FIG. 7A

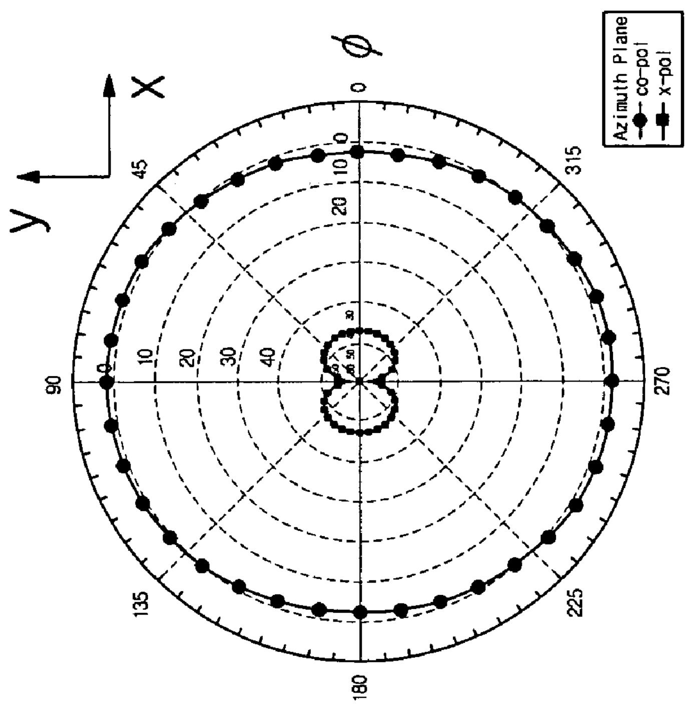
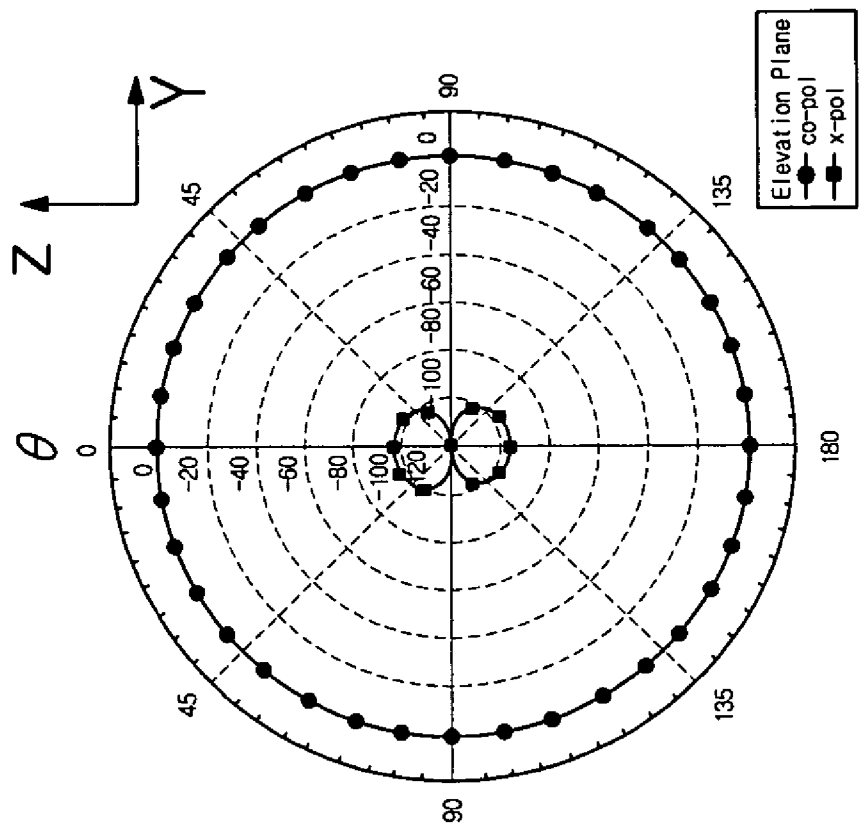

Azimuth Plane
co-pol
x-pol
y
X
φ
0
45
90
135
180
225
270
315

FIG. 7C


θ
Z
Y
0
45
90
135
180
0
-20
-40
-60
-80
-100
-120
Elevation Plane
co-pol
x-pol

LOOP ANTENNA HAVING MATCHING CIRCUIT INTEGRALLY FORMED

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority from Korean Patent Application No. 10-2006-0074501 filed on August 8, 2006, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

Apparatuses consistent with the present invention relate to a loop antenna having a matching circuit integrally formed. More particularly, the present invention relates to a loop antenna having a matching circuit integrally formed thereon to facilitate design and modification of the matching circuit and reduce the antenna size.

2. Description of the Related Art

Mostly, loop antennas are formed in a loop shape such as quadrangle and circle, and utilized in various fields according to the antenna length.

The loop antenna features low input resistance. The design of the loop antenna should take account of its length to match to input resistance 50Ω of the general antenna.

As for the square loop antenna, the input resistance approximates 50Ω and the input reactance approximates zero when the loop length is close to one wavelength in the impedance curve. That is, only when the length of the loop antenna is designed to one wavelength, resonance is generated to the loop antenna.

Also, a radiation pattern of the loop antenna differs depending on the length of the loop antenna. For instance, when the length of the loop antenna is shorter than one wavelength, the radiation is produced along the plane of the loop antenna. When the length of the loop antenna is longer than one wavelength, the radiation is generated perpendicular to the plane of the loop antenna. Thus, in order to regulate the radiation pattern of the loop antenna, the length of the loop antenna is adjusted.

Yet, in adjusting the radiation pattern by making the length of the loop antenna shorter or longer than one wavelength, it is hard to match the input resistance and the input reactance because of the properties of the loop antenna. Accordingly, when the length of the loop antenna is shorter or longer than one wavelength, a separate matching circuit is required for the matching of the input resistance and the input reactance.

However, space is required for the installation of the separate matching circuit. Additionally, after mounting the matching circuit on the device, it is not easy to change the design of the matching circuit because of the interaction with other circuit elements.

Therefore, it is desirable to reduce the size of the device having the loop antenna and facilitate the design of the matching circuit by minimizing the space occupied by the matching circuit at the design phase of the loop antenna.

SUMMARY OF THE INVENTION

Exemplary embodiments of the present invention overcome the above disadvantages and other disadvantages not described above. Also, the present invention is not required to overcome the disadvantages described above, and an exemplary embodiment of the present invention may not overcome any of the problems described above. An aspect of the present invention is to provide a loop antenna having a matching circuit integrally formed thereon, which reduces an installation space and facilitates the design of the matching circuit.

According to an aspect of the present invention, a loop antenna having a matching circuit integrally formed includes a radiator which is formed in a loop shape; and a matching circuit which includes an extension part extended from one side of the radiator to an inner side of the loop and a bend part bent from an end of the extension part several times.

One side of the radiator may be open, one open end may be a feed point, the other open end may be a short point, and the extension part may include of a pair of extension lines which extend from an area opposite to the open side.

The bend part may include of a pair of meander lines which are bent in a zigzag fashion several times from ends of the extension lines in a cross direction, and ends of the meander lines may be connected to each other.

The extension part may serve as a capacitor and the bend part may serve as an inductor to configure an LC circuit.

The matching circuit may control an input reactance.

A resonant frequency may lower as a length of the extension part extends. A resonant frequency may lower as a length of the bend part, which is formed in a cross direction of the extension part, extends.

The loop antenna may further include a resistance control part which is formed along the inner side of the radiator in parallel at an interval from the radiator.

The resistance control part may include of a pair of control lines which extend from the feed point and the short point, respectively, up to an area adjacent to the extension part.

The resistance control part may control an input resistance by functioning as a stub of a dipole type.

A total length of the extension part and the bend part may be about 1λ.

BRIEF DESCRIPTION OF THE DRAWINGS

The above aspects and features of the present invention will be more apparent by describing certain exemplary embodiments of the present invention with reference to the accompanying drawings, in which:

FIG. **1** is a plane view of a loop antenna according to an exemplary embodiment of the present invention;

FIG. **2** is an equivalent-circuit diagram of the matching circuit of FIG. **1**;

FIG. **3** depicts circuits showing changes of electric field and current according to phase variation of the matching circuit of FIG. **1**;

FIG. **4** is a graph showing changes of resonant frequency according to an adjustment of length T**1** of the extension part in the loop antenna of FIG. **1**;

FIG. **5** is a graph showing changes of resonant frequency according to an adjustment of width T**3** of the bend part in the loop antenna of FIG. **1**;

FIG. **6** is a graph showing an S**11** characteristic of the loop antenna according to an exemplary embodiment of the present invention; and

FIGS. **7**A through **7**C are graphs showing radiation characteristics of the loop antenna of FIG. **1**.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS OF THE PRESENT INVENTION

Exemplary embodiments of the present invention will be described in detail with reference to the annexed drawings. In the drawings, the same elements are denoted by the same reference numerals throughout the drawings. In the following description, detailed descriptions of known functions and configurations incorporated herein have been omitted for conciseness and clarity.

FIG. **1** is a plane view of a loop antenna according to an exemplary embodiment of the present invention.

The loop antenna includes a radiator **10** for radiating electromagnetic waves and a matching circuit **20** for adjusting an input reactance of the loop antenna. The radiator **10** and the matching circuit **20** are mounted on a circuit board and spaced apart at an interval.

The radiator **10** is formed in a loop shape such as square and circle. In FIG. **1**, the radiator **10** of the square loop is depicted. The radiator **10** is formed with a conductive wire or a strip line having one wavelength in length. One side of the radiator **10** is open and its both open ends are bent toward the circuit board. The both ends are connected to a resonator (not shown). One end becomes a feed point **11** and the other end becomes a short point **13**. The feed point **11** receives current from the resonator and the short point **13** provides the residual current to the resonator. The radiator **10** is about 1λ in length.

The matching circuit **20** is configured within the loop of the radiator **10**.

The matching circuit **20** includes an extension part **21** connected to the radiator **10**, a bend part **25** connected to the extension part **21** and bent several times, and a resistance control part **30** formed along the inner side of the radiator **10**.

The extension part **21** includes of a pair of extension lines which extend inward from one side of the radiator **10**. One of the extension lines is connected to the feed point **11** and the other is connected to the short point **13**. The extension lines extend toward the inside of the radiator **10** to a certain length T**1** in parallel, and serve as a capacitor.

The bend part **25** includes of a pair of meander lines which are connected to the ends of the extension lines and bent zigzag several times in the cross direction of the extension lines, respectively. Ends of the meander line are connected to each other. The bend part **25** serves as an inductor.

As such, since the extension part **21** serves as the capacitor and the bend part **25** serves as the inductor, the matching circuit **20** configures an LC resonant circuit as shown in FIG. **2**.

FIG. **3** depicts matching circuits a-d showing changes of electric field and current according to phase variation of the matching circuit of FIG. **1**. in each of the matching circuits a-d, the upper diagrams depict the electromagnetic field distribution in the loop antenna, and the lower diagrams depict the current distribution in the loop antenna.

Specifically, matching circuit a depicts the electromagnetic field and the current distribution within the loop antenna at a phase of 45 degrees. The electromagnetic field distribution shows the electromagnetic field is generated only over the extension part **21** functioning as the capacitor. Matching circuit b exhibits the magnetic field is generated over the bend part **25** functioning as the inductor at a phase of 135 degrees. Next, the electromagnetic field is generated over the extension part **21** at a phase of 225 degrees as shown in matching circuit c. At a phase of 315 degrees, the magnetic field is generated over the bend part **25** as shown in matching circuit d.

As the extension part **21** functions as the capacitor and the bend part **25** functions as the inductor, the electromagnetic field and the magnetic field are produced to the extension part **21** and the bend part **25** in an alternating manner according to the phase variation. This is the same principle as the resonance produced to the LC resonant circuit. As one can see from matching circuits a-d, the matching circuit **20** functions as the LC resonant circuit.

Meanwhile, the total length of the extension part **21** and the bend part **25** is about 1λ, and produce the standing wave. It is possible to control the input reactance and the resonant frequency of the loop antenna using the matching circuit **20**.

FIG. **4** is a graph showing changes of the resonant frequency according to the adjustment of length T**1** of the extension part **21** in the loop antenna of FIG. **1**.

FIG. **4** shows the resonant frequency when the length T**1** of the extension part **21** is 4 mm, 8 mm, 12 mm, and 16 mm. When the length T**1** of the extension **21** is 4 mm, the resonant frequency is generated at about 1.15 GHz. The resonant frequency is generated at about 1.0 GHz for 8 mm, about 0.95 GHz for 12 mm, and about 0.87 GHz for 16 mm.

That is, the greater length T**1** of the extension part **21**, the greater capacitive property. As the total length of the matching circuit **20** increases, the resonant frequency band lowers. Hence, the resonant frequency can be shifted by adjusting the length T**1** of the extension part **21**.

FIG. **5** is a graph showing changes of resonant frequency according to the adjustment of width T**3** of the bend part **25** in the loop antenna of FIG. **1**.

FIG. **5** shows the resonant frequency when the width T**3** of the bend part **25** is 4 mm, 8 mm, 12 mm and 16 mm. The resonant frequency is generated at about 1.5 GHz for 4 mm, about 1.2 GHz for 8 mm, about 1.0 GHz for 12 mm, and about 0.9 GHz for 16 mm.

That is, the greater width T**3** of the bend part **25**, the greater inductive property. As the length of the meander lines is extended, the resonant frequency lowers. Hence, the resonant frequency can be shifted by adjusting the width T**3** of the bend part **25**.

The resistance control part **30** is bent inward from the feed point **11** and the short point **13** in parallel with the radiator **10** and extended along the inner side of the radiator **10** in parallel with the radiator **10** at an interval. The end of the resistance control part **30** is extended up to an adjacent area of the extension part **21**. Accordingly, the resistance control part **30** is formed in a "⊏"shape along the radiator **10** to thus configure a pair of control lines facing each other.

Since the resistance control part **30** is configured as the pair of the control lines facing each other, it functions as a stub of a dipole type. Thus, the resistance control part **30** can control the input resistance of the loop antenna and enables the impedance matching when the resonant frequency is changed according to the adjustment of the lengths of the extension part **21** and the bend part **25** by compensating the characteristic of the loop antenna with the low input resistance.

FIG. **6** is a graph showing an S**11** characteristic of the loop antenna according to an exemplary embodiment of the present invention.

FIG. **6** shows the S**11** characteristic of the loop antenna designed by setting the lengths of the radiator **10**, the extension part **21**, the bend part **25**, and the resistance control part **30** to certain values according to an exemplary embodiment of the present invention. As shown in FIG. **6**, the loop antenna produces the resonant frequency at about 0.91 GHz. At this time, the bandwidth at −10 dB is 6.6 MHz or so between 0.9090 GHz and 0.9156 GHz. The gain of the loop antenna is measured to −0.8732 dB. In conclusion, the loop antenna of the exemplary embodiment of the present invention is available in the corresponding band and particularly, suitable for an antenna of the Radio Frequency Identification (RFID) system.

FIGS. **7**A through **7**C are graphs showing radiation characteristic of the loop antenna of FIG. **1**.

In the plane of the loop antenna, when defining the width T**3** direction of the bend part **25** as the x axis, the length T**1** direction of the extension part **21** as the y axis, and the perpendicular direction to the plane of the loop antenna as the z axis, FIG. **7**A shows the radiation pattern in view of the x-y axis, FIG. **7**B shows the radiation pattern in view of the z-x axis, and FIG. **7**C shows the radiation pattern in view of the z-y axis.

In FIGS. **7**A through **7**C, the loop antenna exhibits omnidirectionality with respect to the planes. This implies the matching circuit **20** mounted on the loop antenna does not affect the radiation pattern of the loop antenna.

As such, the loop antenna is integrally formed with the matching circuit **20**. Thus, the matching circuit **20** does not require additional space and thus reduces the size of the device to which the antenna is installed. Also, the resonant frequency can be changed by controlling the capacitor component and the inductor component through the simple adjustment of the length of the extension part **21** and the width of the resistance control part **30**. Therefore, the design modification of the matching circuit **20** is facilitated.

In light of the forgoing, the exemplary embodiments of the present invention reduce the space for the installation of the loop antenna and facilitates the design modification of the matching circuit.

The foregoing exemplary embodiments are merely exemplary and should not to be construed as limiting the present invention. The present teaching can be readily applied to other types of apparatuses. Also, the description of the exemplary embodiments of the present invention is intended to be illustrative, and not to limit the scope of the claims, and many alternatives, modifications, and variations will be apparent to those skilled in the art.

What is claimed is:

1. A loop antenna comprising:

a radiator which is formed in a loop; and

a matching circuit, integrally formed with the loop antenna, which comprises an extension part which extends from one side of the radiator to an inner side of the loop and a bend part bent from an end of the extension part,

wherein the matching circuit is disposed inside the radiator,

wherein one side of the radiator is open, a first open end is a feed point, a second open end is a short point, and the extension part comprises a pair of extension lines which extend from an area opposite to the open one side.

2. The loop antenna as claimed in claim **1**, wherein the bend part comprises a pair of meander lines which are bent in a zigzag shape from ends of the extension lines in a cross direction, and ends of the meander lines are connected to each other.

3. The loop antenna as claimed in claim **2**, wherein the pair of meander lines includes a first meander line and a second meander line, and the first meander line and the second meander line have a mirror symmetry with respect to each other about an axis which dissects the open one side, wherein the first meander line and the second meander line have vertical portions which are parallel to the axis and horizontal portions which are perpendicular to the axis, and wherein the horizontal portions are longer than the vertical portions.

4. The loop antenna as claimed in claim **1**, wherein the matching circuit controls an input reactance.

5. The loop antenna as claimed in claim **1**, wherein a resonant frequency lowers as a length of the extension part extends.

6. The loop antenna as claimed in claim **1**, wherein a resonant frequency lowers as a length of the bend part, which is formed in a cross direction of the extension part, extends.

7. The loop antenna as claimed in claim **1**, wherein a total length of the extension part and the bend part is substantially equal to 1λ.

8. The loop antenna as claimed in claim **1**, wherein the matching circuit is disposed inside the radiator loop.

9. The loop antenna as claimed in claim **1**, wherein a length of the extension part is fixed to correspond to a predetermined resonant frequency of the loop antenna.

10. A loop antenna comprising:

a radiator which is formed in a loop; and

a matching circuit, integrally formed with the loop antenna, which comprises an extension part which extends from one side of the radiator to an inner side of the loop and a bend part bent from an end of the extension part,

wherein the matching circuit is disposed inside the radiator,

wherein the extension part serves as a capacitor and the bend part serves as an inductor to configure an LC circuit.

11. A loop antenna comprising:

a radiator which is formed in a loop;

a matching circuit, integrally formed with the loop antenna, which comprises an extension part which extends from one side of the radiator to an inner side of the loop and a bend part bent from an end of the extension part; and

a resistance control part which is formed along an inner side of the radiator in parallel at an interval from the radiator,

wherein the matching circuit is disposed inside the radiator.

12. The loop antenna as claimed in claim **11**, wherein one side of the radiator is open, a first open end is a feed point, and a second open end is a short point.

13. The loop antenna as claimed in claim **12**, wherein the resistance control part comprises a pair of control lines which extends from the feed point and the short point, respectively, up to an area adjacent to the extension part.

14. The loop antenna as claimed in claim **11**, wherein the resistance control part controls an input resistance by functioning as a stub of a dipole type.

15. A loop antenna comprising:

a radiator which is formed in a loop; and

a matching circuit, integrally formed with the loop antenna, which comprises an extension part which extends from one side of the radiator to an inner side of the loop and a bend part bent from an end of the extension part,

wherein the matching circuit is disposed inside the radiator,

wherein the bend part comprises a plurality of bends.

* * * * *